WANL-TMI-1785

From : Engineering Mechanics
WIN :
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Subject : Low Cycle Fatigue Tests on Beryllium Reflector Material EML-A.2

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Calculations indicate, that during reactor startup, the induced thermal stresses in the beryllium reflector may be well beyond the elastic portion of the monotonic tension stress-strain diagram. Subsequent thermal cycling will result in reversed stress cycling. This may be severe enough to cause damage by a fatigue process in the highly strained portion of the reflector which results from the plastic deformation caused by the thermal transient.

An extensive program on the behavior of beryllium under large strain cycling conditions has been initiated by Engineering Mechanics because of lack of information relative to this particular problem.

This report covers the results of preliminary tests on dumb-bell type specimens machined from trepanned cores of various sector pressings.

Since the transient strains are in the plastic range, stress amplitude as the controlling variable is misleading in the analysis of low cycle fatigue phenomenon. Thus, strain amplitude, which is more applicable to such analysis, is used as the control variable in our studies.

Previously obtained tensile data at ambient and LN_2 temperatures are included as basic static properties on the as machined specimens since available data (Ref. TME-1106) on this material are based on electrolytically polished specimens which

INFORMATION CATEGORY

Unclassified

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reflect somewhat higher strength values. The monotonic tensile stress-strain curves for vacuum hot pressed beryllium at ambient and LN_2 temperatures are shown in Figure 1. These data were obtained on the same type of specimen as used in the cycling tests. The fractured tensile specimens are shown in Figures 2 and 3.

The strain range for the initial room temperature cycling test was fixed at ± 1700 microstrain. Based on the relationship $N_f = (1/2\ E_f/\Delta E_p)^2$ as proposed by Coffin (1) and Manson (2) the cyclic life could be anywhere from 5 to 250 depending on the fracture strain (E_f) used. The above cyclic life range reflects the spread in elongation values reported in TME-1106 covering properties of 14 pressings.

The above relationship which was established for ductile materials may not necessarily apply to hot pressed beryllium as evidenced from the results shown in Figure 4. The complete strain history of this test sample cycled at ambient temperature is given in the following table.

Spec. Ident.	Temp °R	Strain - μ "/" Total Range	Plastic Range	Cycles
UN-3 3824/104	530	3400 (± 1700)	1600 (± 800)	200 NB
"	"	4000	1950	20 "
"	"	5000	2760	20 "
"	"	6000	3600	10 "
"	"	8000	≈5200	3/4 Broke

Figure 4 shows the stable hysteresis loop of each strain cycle replotted on the X-Y plot of the final cycle. The fractured sample as aligned in the Wiedemann machine along with the X-Y plot of the 20 cycles at 2500 microstrain is shown in Figure 5.

Although the room temperature results indicate no serious damage imposed by the initial strain cycling, this does not necessarily reflect the behavior at cryogenic temperatures where fracture strain limits are seriously impaired. TME-1106 shows average elongation values reduced 80 per cent at -300°F.

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(1) Coffin, Trans. ASME, V76, 931-949, 1954

(2) Manson, NACA, TN-2933, 1953

A second specimen is to be strain cycled at LN_2 temperature and is now being set up.

T. F. Hengstenberg
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Attachments (5)

Reference: TME-1106 Mechanical and Physical Properties of Vacuum Hot Pressed
Beryllium - R. Nadler, Materials

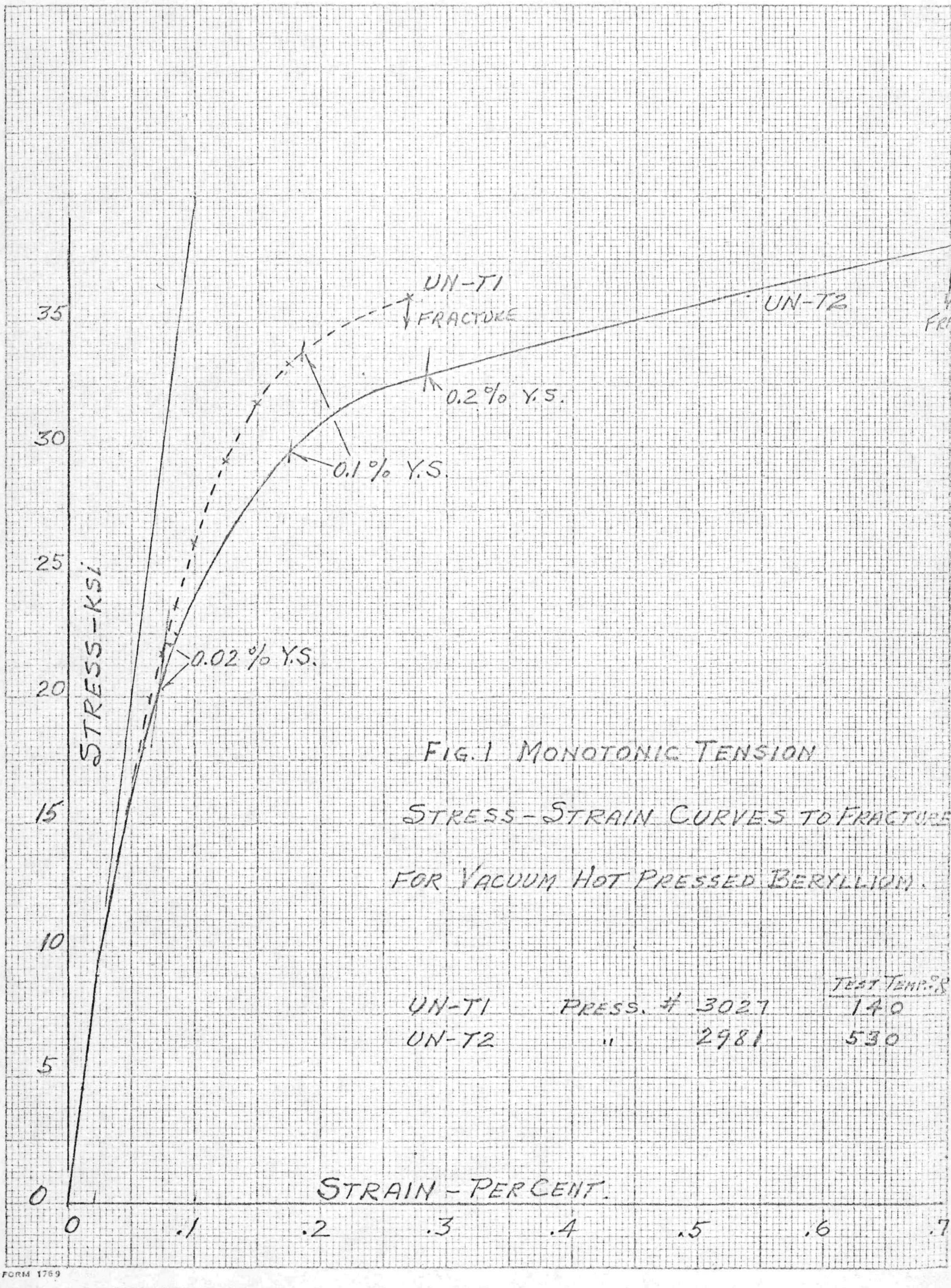


FIG. 1 MONOTONIC TENSION STRESS-STRAIN CURVES TO FRACTURE FOR VACUUM HOT PRESSED BERYLLIUM.

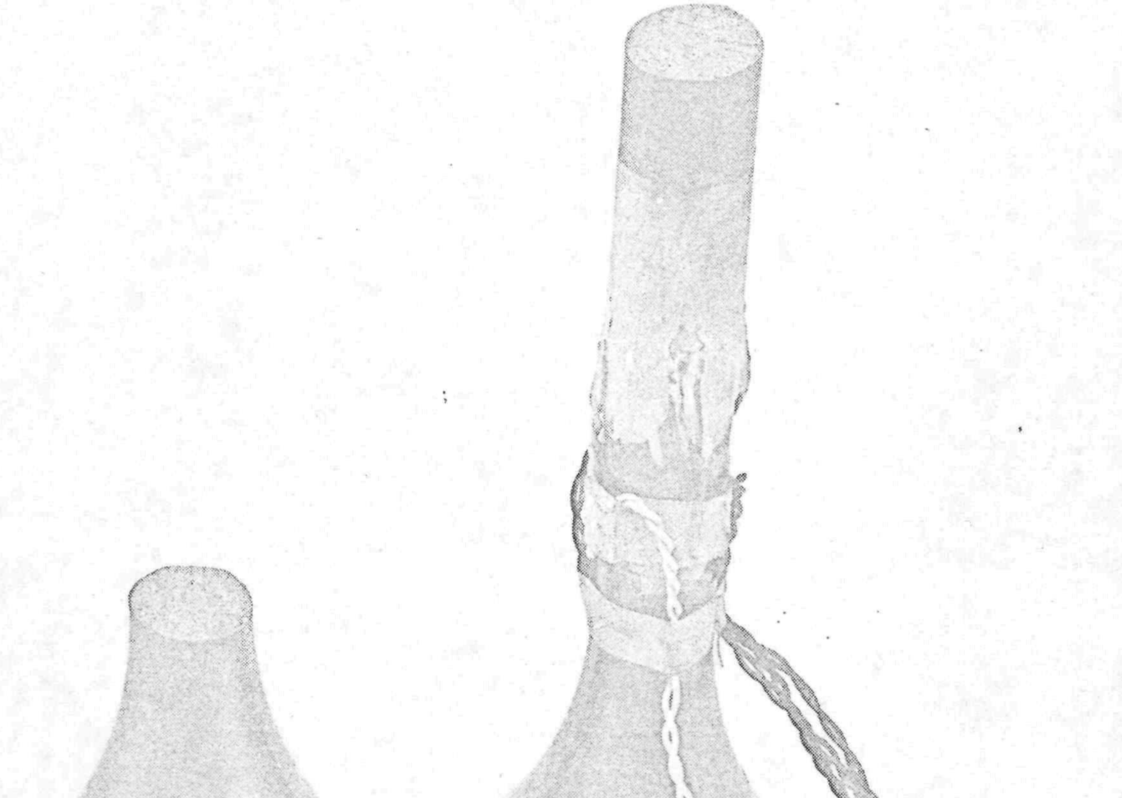


FIGURE 2
MONOTONIC TENSION ROOM TEMP.
FRACTURE PRESSING NO. 2981 BERYLLIUM

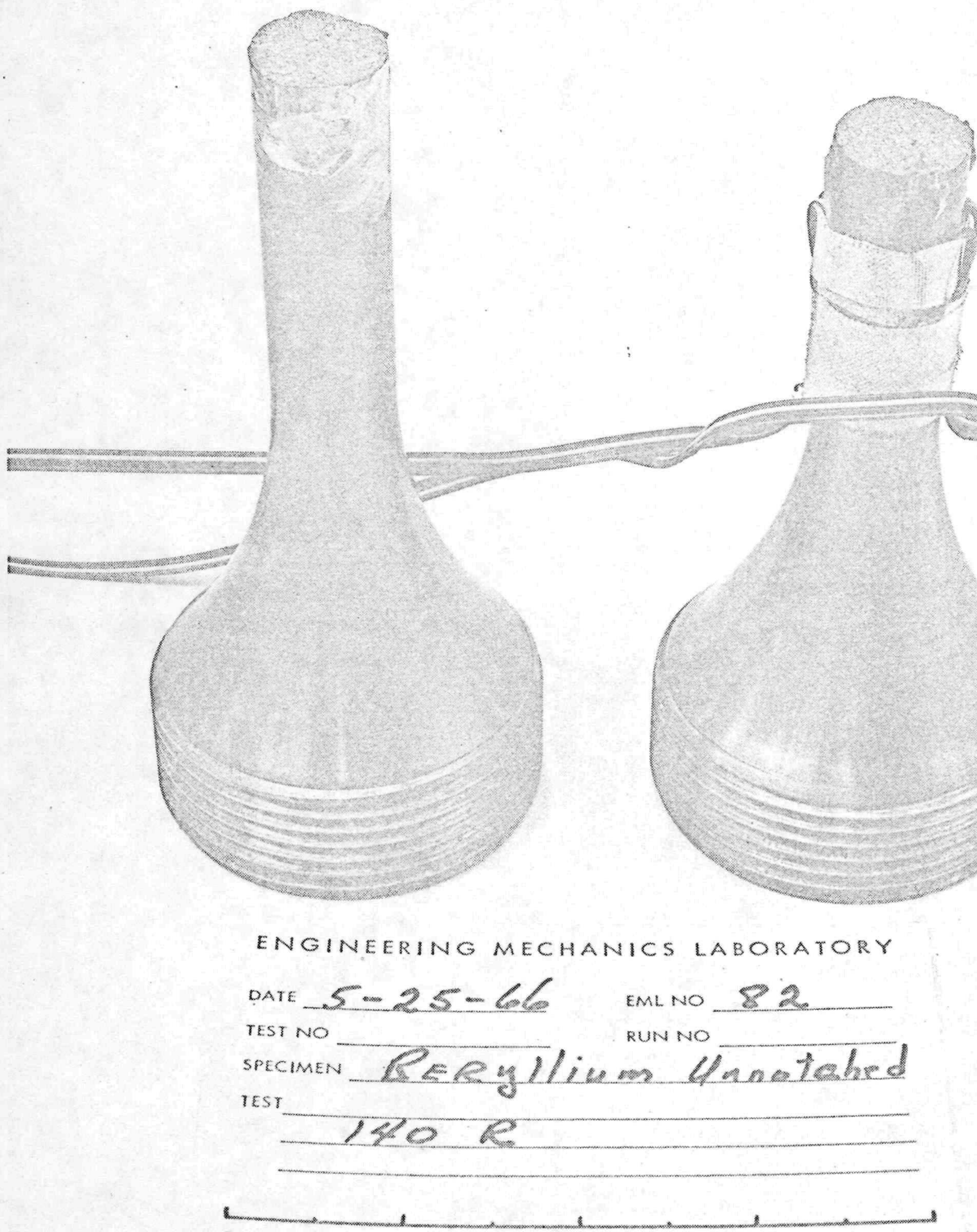
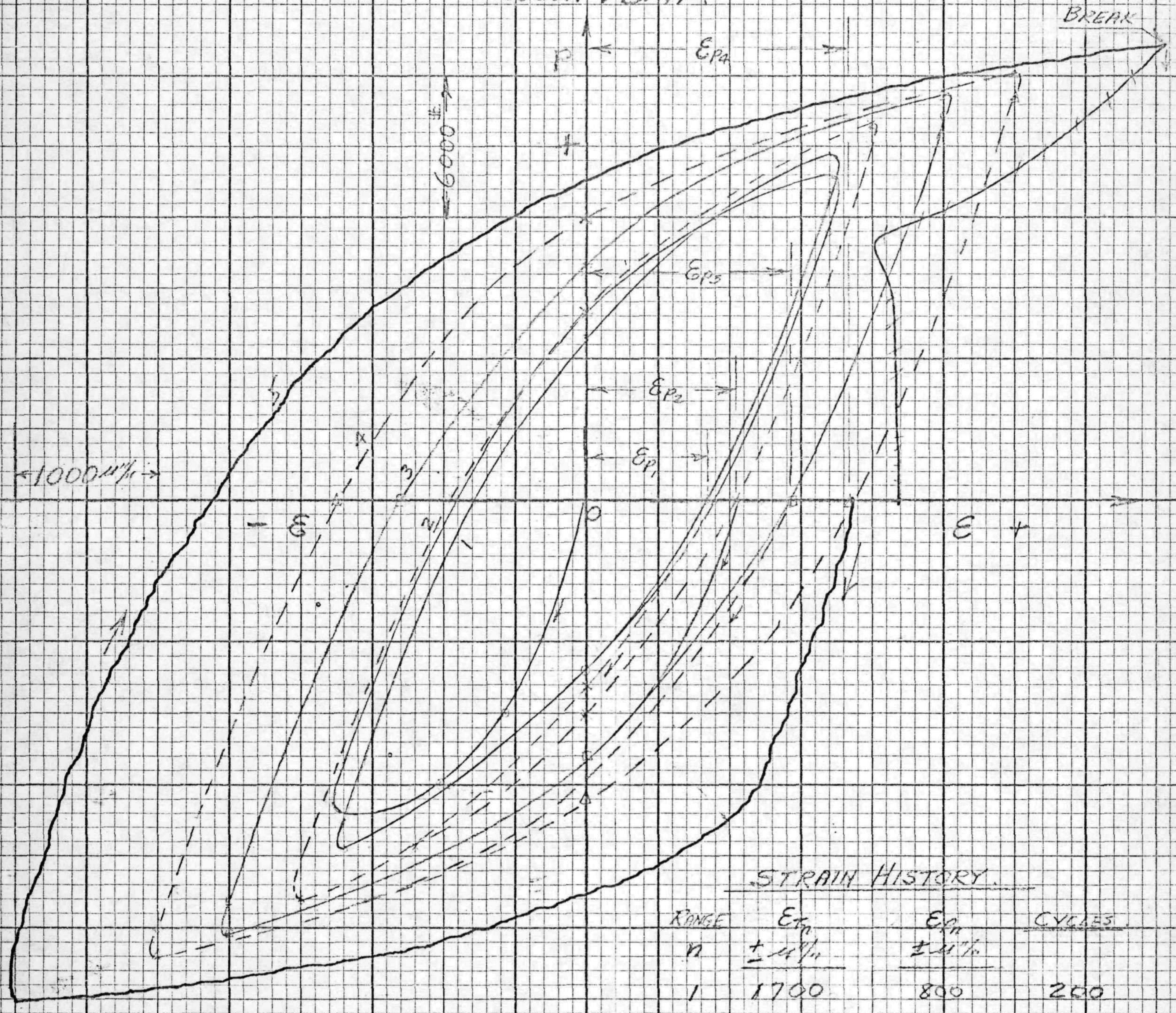


FIGURE 3
MONOTONIC TENSION 140°R FRACTURE
PRESSING NO. 3027 BERYLLIUM

EML 82: STRAIN CYCLING TEST - H.P. BERYLLIUM

SPECIMEN #104 - 3824 PRESSING

Room Temp.



STRAIN HISTORY

RANGE n	ε_{T_n} ± μ"/"	ε_{P_n} ± μ"/"	CYCLES
1	1700	800	200
2	2000	975	20
3	2500	1380	20
4	3000	1800	10
5	4000	2600	3/4 FRAC.

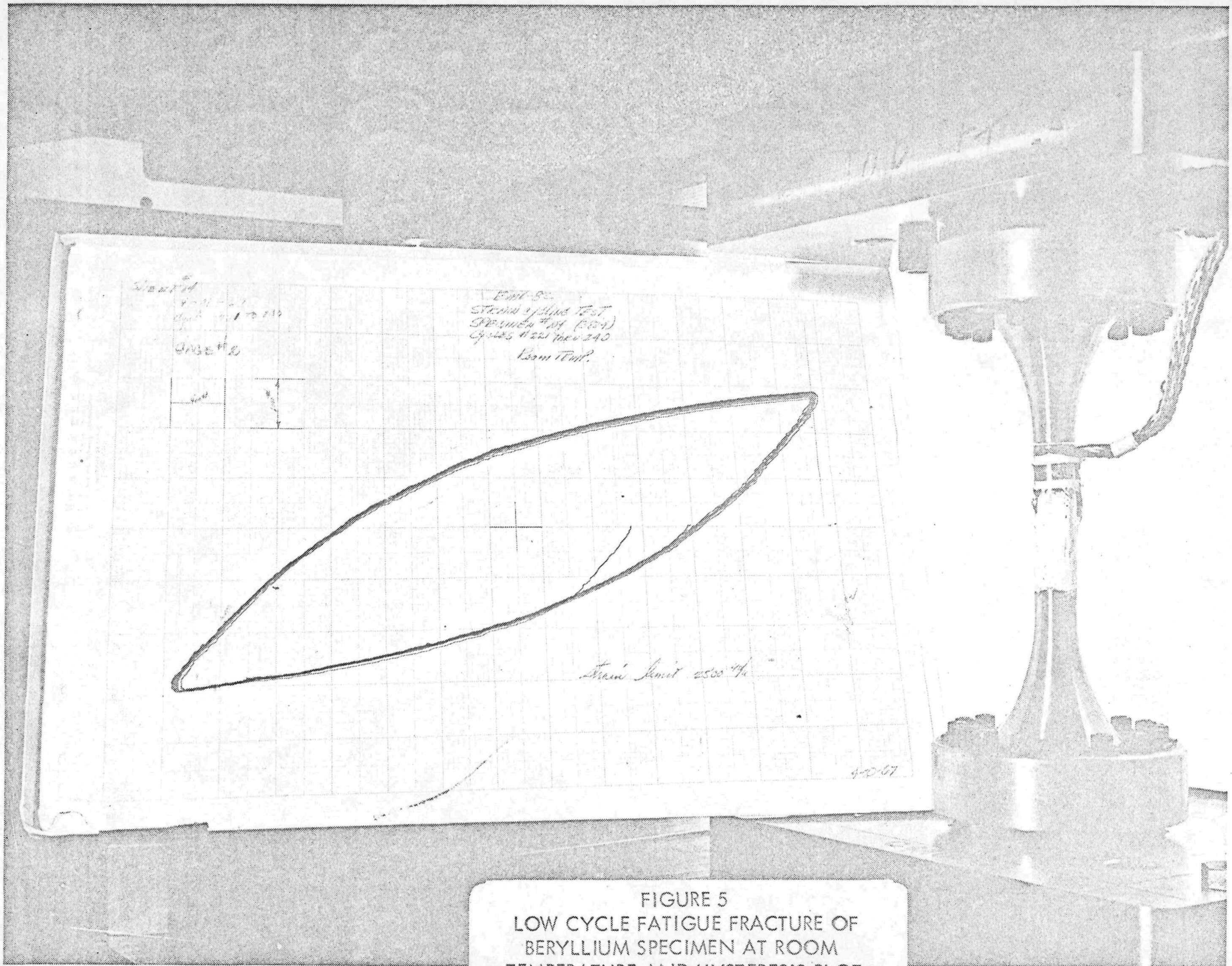


FIGURE 5
LOW CYCLE FATIGUE FRACTURE OF BERYLLIUM SPECIMEN AT ROOM TEMPERATURE AND HYSTERESIS PLOT OF ± 2500 MICROSTRAIN